DOCUMENT RESUME

ED 242 588 SO 015 439

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TITLE Simultaneity in Economics Learning Models.
PUB DATE Sep 83
NOTE 32p.; Paper presented at the Joint Council on Economic Education-National Association of Economics Education Annual Meeting (San Antonio, TX, October 6, 1983).
PUB TYPE Information Analyses (070) -- Speeches/Conference Papers (150)

EDRS PRICE MF01/PC02 Plus Postage.
DESCRIPTORS Academic Achievement; *Economics Education; *Educational Research; Elementary Secondary Education; Higher Education; Learning Processes; *Least Squares Statistics; Models; Student Attitudes
IDENTIFIERS *Simultaneous Equations

ABSTRACT

An explanation of the statistical problems encountered in economics education research with using ordinary least squares (OLS) rather than two-stage least squares (TSLS) in the context of simultaneous structural equations is provided. When endogeneous variables are simultaneously related in a system of equations, alternative statistical estimation procedures, such as TSLS versus the traditional use of OLS, are required. A demonstration of the OLS and TSLS estimation procedures is offered, using as an example the possible simultaneous relationship between economics achievement and attitudes towards economics which has been extensively discussed in the economic education literature. Also reviewed are alternative models to a simultaneous specification suggesting that the achievement-attitude relationship is one requiring joint product rather than simultaneous modeling and estimation procedures. (RM)

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SIMULTANEITY IN ECONOMICS LEARNING MODELS

by

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(September 1983)

SO 015 439

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SIMULTANEITY IN ECONOMICS LEARNING MODELS

In an earlier decade, research studies in economic education often specified a single-equation model with one dependent endogenous variable and several exogenous explanatory variables. Ordinary least squares (OLS) was used to estimate the equation and little attention was given to justifying the exogeneity of the regressors. Some models did include more than one equation, but the direction of the relationship among the endogenous variables was assumed to be one-way or recursive.

A simultaneous relationship, however, may exist among the endogenous variables which can not be expressed in a simple single-equation or multi-equation recursive model. While reciprocal associations among variables were recognized in previous studies, specified models were still estimated with OLS. The appropriateness of this procedure would be questioned today and alternative statistical estimation procedures, such as two-stage least-squares (TSLS), would be used to estimate the structural parameters of these models (Becker, 1983a). Since this simultaneity problem and the necessary statistical methods may not be widely understood, a detailed explanation of these topics is provided in this chapter.

To simply the exposition, only one example of a simultaneous relationship in the economic education production process will be discussed, namely, the association between student achievement in economics and attitudes towards the subject.[1] Student attitudes towards economics have long been thought to contribute to economic understanding in the classroom. A conclusion often drawn from this belief is that time spent by teachers trying to improve student attitudes (i.e., making the subject more interesting and exciting) has a payoff in increased economics achievement. On the other hand, economics achievement may be a potential factor influencing student attitudes towards the subject. The

conclusion drawn from the latter belief is that the more economics a teacher can help students learn, the more they will like the subject. In the extreme this improved attitude may lead to more consumption of and investment in economics information (courses, publications, etc.), or increased retention and application of economics learning. Research on this economics achievement-attitude relationship can be found throughout the economic education literature. Before the statistical characteristics of the simultaneity problem are discussed, a brief review offers the necessary background perspective.

Achievement and Attitude: A Review

One of the first attempts to study attitudes in economics was made by McConnell and Lamphear (1969). Using a survey instrument "designed to quantify the attitude of students towards the course, and more specifically, towards economics as a discipline" (p. 27), they found an insignificant difference in attitudes between students attending the principles course with or without lectures based on a test comparing means. While not explicitly examining the achievement-attitude relationship, this study was noteworthy since it recognized the need to measure outcomes in economics instruction in the affective as well as the cognitive domain.

Paden and Moyer (1971) used the McConnell-Lamphear index as a dependent variable and as an independent predictor of economic achievement in two single-equation models to determine the appropriate length of the principles course. Their results indicated that attitudes towards economics could influence the total economics test score, and that the total economics test score appeared to influenced attitudes. Paden and Moyer, however, concluded with a note of caution about the direction of the relationship:

> "Clearly one of the most important variables in explaining attitudes is the student's score on the test of content - the better the students, the more favorable their attitudes and vice versa. No attempt is made here to suggest the direction of causation - the variable is used simply to stabilize and improve the explanatory power of the analysis" (p. 137).

A study by Ramsett, Johnson, and Adams (1973), which examined the value of instructors in teaching principles, was less cautious in its conclusion about the achievement-attitude association. Two single-equation regression models were specified, with post-TUCE as a dependent variable in equation 1, and as an independent variable in equation 2. Post attitude served as a dependent variable in equation 2, and as an "independent" variable in equation 1. The equations were estimated using OLS. The study concluded that post-TUCE and post attitude are significantly related and were mutually reinforcing: "In other words, as students learn more economics, they tend to like it more, and the more they like it, the more they learn" (p. 60).

More recent single-equation studies examined only one side of the economic achievement-attitude relationship, and reported a significant impact of attitude on achievement. Karstensson and Vedder (1974) found that attitude towards economics directly influenced both course grade in economics, and additional consumption of economics courses. A study by Craig and O'Neill (1976), moreover, showed support for the hypothesis that: "there would be more retention in those classes which had more positive attitudes towards the course and the subject matter" (p. 92). Henry and Ramsett (1978) also found a positive association between student attitude and post-TUCE and concluded that the research study: "helps to substantiate the close association between the cognitive and attitudinal dimensions of learning" (pp. 28-29).

Although most single-equation studies discovered a positive and significant relationship between achievement and attitude, single-equation studies have been criticized by Johnson (1978) for failure to account for the simultaneous equations bias in model estimation. Walstad (1979) made the same criticism and demonstrated the problem in a study of an USMES economics program at the elementary level. After correcting for the possible simultaneous equations bias in OLS estimation, the TSLS estimates indicated that achievement may directly and significantly influenced attitudes, but not vice versa.

For our purposes, the above study is of interest because it represents an initial investigation of achievement-attitude simultaneity. The model is also relatively simple in construction, and therefore can be used to illustrate the characteristics of simultaneous equation estimation using alternative statistical procedures (OLS versus TSLS). Readers interested in the details of study design, measurement procedures, or model rationale should consult the original source for those aspects will be omitted from the discussion.

A Simultaneous Equations Model

Consider a general model of the perceived behavioral relationship between achievement and attitude in economics:

$$ACH = f(ATT, [B], e_1)$$

$$ATT = g(ACH, [C], e_2)$$

Where: ACH = achievement; ATT = attitude; [B] = vector of human capital, utilization, and technology inputs considered to influence achievement; [C] = vector of human capital, utilization, and technology inputs considered to influence attitude formation; and e_1 and e_2 = random error terms for the respective equations. The conceptual model states that achievement depends, except for random error, on attitude and a set of background variables. In

contrast, attitude is expressed as being dependent on achievement plus a set of background variables, except for an error component. The achievement-attitude production processes are interrelated in this conceptual model: attitude is an output, and an input into the production of achievement; achievement is an output, and an input into the production of attitude.

Our study example, which is based on this conceptual model, is stated in linear form for estimation purposes in equations 1 and 2.

$$(1) \quad Y_1 = \beta_{12}Y_2 + \sum_{i=0}^{4} \gamma_{1i}X_i + \sum_{i=6}^{10} \gamma_{1i}X_i + U_1$$

$$(2) \quad Y_2 = \beta_{21}Y_1 + \sum_{i=0}^{3} \gamma_{2i}X_i + \sum_{i=5}^{10} \gamma_{2i}X_i + U_2$$

Where: Y_1 = PTECON (post-test economic understanding); Y_2 = PTATT (post-test attitude towards economics); X_0 = CONSTANT; X_1 = AGE; X_2 = SEX (male or female); X_3 = SES (socioeconomic status); X_4 = PRECON (pretest economic understanding); X_5 = PRATT (pretest attitude toward economics); X_6 and X_7 = GRADE (4th and 5th grade levels); X_8 = ABSENCES (number of absences from school); X_9 = TECON (teacher economic understanding); and, X_{10} = GROUP (control or experimental). U_1 and U_2 are the respective error terms for each equation. (Variables will simply be referred to by capitalized acronomyn or symbols in the following pages.)

At the outset, a distinction should be made between the types of variables in the model. Endogenous variables, as represented by the Y's, are variables whose values are determined by the model. The X's represent exogenous variables whose values are predetermined.[2] In each equation, the dependent variable is

both a function of exogenous variables and an endogenous variable, with the direct effects of exogenous regressor coefficients represented by γ and endogenous regressor coefficients represented by β.

Equations 1 and 2 are referred to as the structural equations for the model to be estimated. Those equations are assumed to model the way theory predicts the observed data were generated. In equation 1, PTECON is considered to be a function of: PTATT (Y_2); AGE (X_1); SEX (X_2); SES (X_3); PTATT (X_4); GRADE levels (X_6 and X_7); ABSENCES (X_8); TECON (X_9); and GROUP (X_{10}); plus a constant term (X_0), and an error term (U_1). On the other hand, PTATT (Y_2) is expressed in equation 2 as a function of: PTECON (Y_1); AGE (X_1); SEX (X_2); SES (X_3); PREATT (X_5); GRADE level (X_6 and X_7); ABSENCES (X_8); TECON (X_9); and GROUP (X_{10}); plus a constant term (X_0), and an error term (U_2). These two structural equations form a model that incorporates a reciprocal, causal link between the two endogenous variables, PTECON (Y_1) and PTATT (Y_2).

Worth noting is the difference in the complex specification of the simultaneous economic learning model compared with a single-equation specification, where each equation is basically considered to be a separate model of reality. A more complete specification is possible with the simultaneous model since each equation can contain both exogenous and endogenous variables. When endogenous variables are believed to be reciprocically related, this feature is explicitly rather than implicitly included in the structural model. With single-equation analysis a simplistic assumption is made <u>a priori</u> that the regressors are determined outside the model and each single equation is separately considered without explicit recognition of the structural equation system implied in the two-single equations.

The inclusion or exclusion of variables, moreover, from each structural equation on theoretical grounds allows for a more sophisticated mapping of

relationships than is possible in a single equation model. PRATT, for example, is excluded from equation 1 where PTECON was the dependent variable. The reason for this exclusion is based on the following "chaining." PRATT is directly related to PTATT, as shown in equation 2 of the model. PTATT, in turn, directly influences PTECON, as shown by the inclusion of Y_2 as a regressor in equation 1. Only a contemporaneous, direct link is assumed to exist between the cognitive and affective domains, and, therefore PRATT only has an indirect effect on PTECON through its direct effect on PTATT. In each structural equation (1 or 2) only the direct effects of variables are included.

Similarly, PRECON was excluded from the structural equation 2 with PTATT as the dependent variable. PRECON was not considered to directly influence PTATT. PRECON does have an indirect effect on PTATT since PRECON directly influences PTECON, and PTECON in turn has a direct influence on PTATT. In this manner, the model specification for the structural equations provides an explicit way to describe the complex direct and indirect relationships between variables, rather than just assuming that all effects are direct, with one-way causality, as would be done in a single-equation model.

The Reduced Form

A cumulative description of these complex relationships can be provided by solving for the reduced-form equations for the economic learning model. The procedure for this two-equation model simply involves substituting the right-hand side of equation 2 into equation 1 as an expression for PTATT. The same procedure can be followed in equation 2, with the right-hand side of equation 1 being substituted into equation 2 as an expression for PTECON. By combining and rearranging terms the reduced form equations are obtained for equation 1 and equation 2 and expressed as equations 3 and 4:

$$(3)\quad Y_1 = [1/(1 - \beta_{12}\beta_{21})][\sum_{i=0}^{3} (\beta_{12}\gamma_{2i} + \gamma_{1i})X_i + (\gamma_{14})X_4 + (\beta_{12}\gamma_{25})X_5$$

$$+ \sum_{i=6}^{10} (\beta_{12}\gamma_{2i} + \gamma_{1i})X_i + (\beta_{12}U_2 + U_1)]$$

$$(4)\quad Y_2 = [1/(1- \beta_{21}\beta_{12})][\sum_{i=0}^{3} (\beta_{21}\gamma_{1i} + \gamma_{2i})X_i + (\beta_{21}\gamma_{14})X_4 + (\gamma_{25})X_5$$

$$+ \sum_{i=6}^{10}(\beta_{21}\gamma_{1i} + \gamma_{2i})X_i + (\beta_{21}U_1 + U_2)]$$

These reduced-form equations are merely a solution of the structural equations so that each endogenous variable appears in only one equation, is on the left-hand side of that equation, and is a function only of exogenous variables. The reduced-form and the structural equations are alternative representations of the same model in that both describe the relationship between economic achievement and attitude in the classroom. The reduced-form and the structural equations, however, provide different information and require different estimation procedures. The reduced-form equations summarize the entire structural model in terms of the <u>total</u> change expected in each endogenous variable from a change in any one of the exogenous variables. The structural equations, on the other hand, provide the <u>direct</u> effects of included variables on the endogenous dependent variable in each equation.

This total or cumulative effect for the reduced-form equations can be illustrated by examining the reduced-form coefficients derived in equations 3 and 4. The coefficient for SES (X_3) in equation 3 is restated below for analysis:

$$\frac{\gamma_{13} + \beta_{12}\gamma_{23}}{1 - \beta_{12}\beta_{21}} X_3$$

The first term in the numerator, (γ_{13}), represents the direct effect on PTECON from a change in SES, as would be found in the structural equation 1. Added to this direct effect is the term ($\beta_{12}\ \gamma_{23}$) representing the indirect effect on PTECON due to a change in PTATT, the latter arising directly from a change in SES. Finally, the term $\frac{1}{1 - \beta_{12}\beta_{21}}$ is a multiplier that arises from the reciprocal effect of PTECON and PTATT on one another. A component analysis of the total effect for each exogenous variable can be conducted in a similar manner as necessary.

Problems in Parameter Estimation

Of more interest in most empirical work and in this achievement-attitude example are the estimates of the direct effects of variables in the structural equations. Estimates of the direct effects cannot usually be obtained by estimating the reduced-form equations which only require the use of OLS.[4] Unfortunately, a simultaneous equations model requires the use of the more complicated TSLS procedures.

Why TSLS? For OLS estimation procedures to be applied to each of the structural equations of the model, a number of assumptions about the error terms would have to be met. That is, the conditions (1) through (5) would be assumed about the error terms, where U_i represents the error terms in equations i=1, . . . n and E( ) represents the expected value operator:

(1) $E(U_i) = 0$ for all i

(2) $E(U_i U_j) = \sigma^2$, where i = j

(3) $E(U_i U_j) = 0$, where $i \neq j$

(4) $E(U_t U_{t+s}) = 0$, where s refers to all time periods other than the period indicated by t

(5) $E(U_i X_i) = 0$, where X_i denotes the regressors.

Conditions (1) through (5) state that the residuals have a zero mean, constant and finite variance, zero covariance between or within an equation, no residual correlation across time within or between equations, and that the error term is independent of the regressors.

If all of the conditions are fulfilled, then OLS estimates are unbiased and consistent. When a simultaneous relationship exists, then condition (5) is violated. That is, $E(U_1X_1) \neq 0$. The error term in an equation and the endogenous regressor are correlated and OLS procedures may produce biased and inconsistent estimates of the parameters. On the other hand, the reduced-form equations express each endogenous variable as a function of only exogenous variables. In the reduced-form equations condition (5) is not violated. Assuming that conditions (1) through (4) are met, OLS estimation procedures can be used to obtain unbiased and consistent estimates of the total effect, but not in most cases, the direct effect of variables.

The simultaneous equation bias inherent in the structural equations can be shown by examining the relationship between the error term in equation 1 (U_1) and the endogenous explanatory variable PTATT (Y_2). For no bias to exist, the correlation between the variables would be expected to be zero. It is known, though, from solving for the reduced-form equation 4 for Y_2, that U_1 is part of the error term for Y_2. Therefore, the explanatory variable Y_2 in the structural equation 1 is correlated with the error term U_1 since:

$$E\{U_1[Y_2 - E(Y_2)]\} = E\left[U_1 \cdot \frac{\beta_{21}U_1 + U_2}{1 - \beta_{21}\beta_{12}}\right] = \frac{\beta_{21}}{1 - \beta_{21}\beta_{12}} E(U_1^2) \neq 0.$$

The error term for the structural equation 2 (U_2) is also correlated with the endogenous explanatory variable PTECON Y_1 since:

$$E\{U_2[Y_1 - E(Y_1)]\} = E\left[\, U_2 \cdot \frac{\beta_{12}U_2 + U_1}{1 - \beta_{12}\beta_{21}} \,\right] = \frac{\beta_{12}}{1 - \beta_{12}\beta_{21}} E(U_2^2) \neq 0.$$

As a consequence of the correlated error terms, OLS estimation of each of the structural equations can be expected to produce biased and inconsistent estimates of a parameter. The estimated variances of the regressor coefficients are also dependent on the estimation of the variance of the error terms (U_1 or U_2), causing estimated variances of the coefficients to be biased. All test statistics are suspect and cannot be relied on for the rejection of the null hypotheses concerning regressor effects.

Two-Stage Least Squares

An alternative to estimating the parameters using OLS is TSLS. TSLS works as follows using the economic learning model as an example: In the first stage, the reduced-form equations 3 and 4 are estimated using OLS procedures, which involves regressing Y_1 (PTECON) and Y_2 (PTATT) on all the exogenous variables in the model, X_1 through X_{10}. In the second stage, the structural equations 1 and 2 are estimated using the predicted values $\hat{Y}_1$ and $\hat{Y}_2$ in the structural equations. That is, structural equation 1 is estimated by regressing Y_1 against $\hat{Y}_2$, and X_1 to X_4 and X_6 to X_{10}. Similarly, equation 2 is estimated by regressing Y_2 against $\hat{Y}_1$, and X_1 to X_3 and X_5 to X_{10}.

The basic idea in TSLS is to substitute for the endogenous variable on the right-hand side of an equation, which is correlated with the residuals, a linear function of all exogenous variables, which is not correlated with the residuals. An example of these linear functions are the estimated values $\hat{Y}_1$, $\hat{Y}_2$ from the reduced-form equations. Since the predicted values, $\hat{Y}_1$ and $\hat{Y}_2$, are uncorrelated with the error terms in probability limit, this TSLS procedure will give consistent estimates for the coefficients in each equation.

The major difference between estimating the structural equations 1 and 2 of the economics learning model by OLS and TSLS is consistency. By definition, an estimator is a consistent if, as the sample size tends to infinity, the probability approaches unity that the estimated parameter differs from the true parameter by less than an arbitrarily small amount.[3] In other words, as the sample size becomes very large, it is desirable for the estimator $\hat{\beta}$ to converge or get close to the true value of β. As was shown earlier, this large sample or asymptotic property holds for TSLS estimates; it does not hold for OLS estimates of the parameters in this simultaneous equation system.

Identification

One other matter requires some discussion before TSLS estimation procedures can be applied to the structural equations of the model. Identification refers to the fact that unless enough prior constraints are imposed on the set of equations that make up the model, it may be impossible, without reformulating the model, to derive a unique set of parameter estimates for some of the equations.

To use TSLS, all of the equations must be exactly identified or over-identified. One condition for an equation to be identified is a simple counting rule can be used which requires that the number of predetermined or exogenous variables excluded from the equation must be greater than or equal to the number of endogenous variables included in the equation less one. The list of included endogenous variables should contain variables on both the left-and right-hand sides of the equation. In equation 1, for example, one exogenous variable PRATT has been excluded and two endogenous variables have been included. Equation 1 of the model is exactly identified. Similarly, in equation 2 PRECON is excluded but two endogenous variables are included so that this equation is also exactly

identified.[4] This condition, referred to as the order condition, is a necessary condition for identification of the model.

A necessary and sufficient condition for identification is the rank condition. Using procedures suggested by Maddala (1977, pp. 223-225). We can illustrate the application of this condition to our two-equation model using the followng chart:

	Y_1	Y_2	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}
Eq. 1	*	*	*	*	*	*	0	*	*	*	*	*
Eq. 2	*	*	*	*	*	0	*	*	*	*	*	*

A star (*) indicated that a variable is included in the equation and a zero (0) indicates that a variable is excluded from the equation. For a particular equation, delete that row and select just the columns corresponding to the elements which have zeros in that row. The equation is identified (either exactly or over), if a matrix of rank M-1 can be formed from the columns, where M equals the number of equations or endogeneous variables in the system.

In equation 1, the first row is deleted and the column picked up corresponding to the excluded variable X_5. What is the rank of that matrix? To be identified it should be at least of rank 1, because we have 2 equations or endogeneous variable in the system for a required matrix of 1 (2-1). The matrix looks like [*] and is of rank 1, so that first equation is identified. Similarly for equation 2, we delete that row and form a matrix of the columns that have zero or exclude elements in that row. X_4 is the only excluded element from equation 2 and a matrix which looks like [*] and has a rank of 1 is formed from that column. Equation 2 is also identified since rank of the matrix is equal to the number of equations less 1. The two equation model is identified and can be estimated using TSLS.

The rank condition is a necessary and sufficient condition for identification, but the order condition is only necessary one. To see the distinction, consider what would have occurred if X_5 had been the only variable excluded from equation 1 and 2, and X_4 was included in both equations. Using the order condition, which simply looks at each equation separately, we would say that equation 1 is identified because the number of excluded predetermined variables is greater than or equal to the number of included endogeneous variables less one ($1 \geq 2 - 1$). Using our rank procedure, where we delete the row for equation 1 and pick up the excluded variable columns, we find that the resulting matrix looks like [0] and has rank of zero. Since zero is not greater than or equal to the number of equations less one, the equation is not identified ($0 \not\geq 2-1$). A similar analysis will produce the same result for equation 2. To be certain that a model is identified for TSLS estimation purposes, the rank condition must be satisfied. The subject of identification, however, is more complex than can be presented here and a standard econometric text should be consulted for further discussion of the rank condition and alternative forms of identification.

It should also be noted that the decision to exclude PRATT from equation 1 and PRECON from equation 2 was based on a priori theoretical considerations and was not done arbitarily for the purposes of identification. As stated earlier, the exclusion of these variables from their respective equations was based on what was considered to be a more realistic "chaining" of effects expressed in the structural equations of the model. That is, PRATT → PTATT → PTECON versus the more simplistic representation PRATT → PTECON in equation 1 and PRECON → PTECON → PTATT versus the more simplistic representation PRECON → PTATT in equation 2. The model specified a contemporaneous relationship between attitude and economic understanding, with a lagged relationship existing only within, but not between, the affective and cognitive domains.

There is no reason, aside from theory, why these exogeneous variables (PRECON or PTATT) could not be included in the model and other variables arbitarily excluded in order to identify the model. But, decisions concerning inclusion of exclusion of variables should be made based on theory or previous research and not on the basis of the need for identification. The basic model should be specified first, and then attention focused on the identification of equations in the model. Otherwise, the model may not reflect the perceived structural relationships even though the appropriate statistical techniques have been applied in estimating the identified equations.

OLS and TSLS: Results

The effects of the simultaneous equation bias can best be illustrated by comparing the OLS and TSLS estimates of the structural parameters of the economic learning model in Table 1. With structural equation 1, both estimation procedures show the equation to be significant ($F = 36.602$) and the adjusted R squares of .517 indicate that more than half of the variance in the data is explained by the equation. The direction of the sign and the size of the coefficients are also similar for both OLS and TSLS estimation procedures. The most striking difference, however, is the significance test of the effect of the endogenous regressor, PTATT, on the dependent variable, PTECON. The OLS estimate indicates that the relationship is significant ($t = 2.445$; $p < .01$). The TSLS estimate shows the effect of attitude on achievement in economics to be insignificant ($t = .745$; $p > .05$). The use of the inconsistent OLS estimate would lead to the rejection of a true null hypothesis (a type I statistical error), that PTATT has no significant effect on PTECON after controlling for the influence of other variables.

Insert Table 1 about here

One possible reason for the different test results is the nature of the standard errors for the OLS and TSLS estimates. In general, the standard errors obtained from the TSLS estimates are greater than those for the OLS estimates, but these differences do not mean that the OLS method is better. The standard errors from the OLS method cannot be the correct ones as those estimates do not control for the simultaneous relationship that may exist. All test statistics using OLS estimates are suspect and cannot be relied upon for the rejection of the null hypothesis. The TSLS estimates are at least asymptotically the correct estimates within the equation system considered.[5]

The overall equation F for equation 2 is highly significant ($p < .01$) by both the OLS and TSLS estimates. The adjusted R^2 of .232 indicates the equation explains 23 percent of the variance in the data, a good result in relation to much attitude research in education. The OLS and TSLS estimates of the structural parameters for equation 2 reveal that PTECON significantly influences PTATT. In fact, as shown by the TSLS estimate in Table 1, each point a student obtains on the PTECON measure contributes .223 of a point, on average, to the prediction of the post-test attitude score, ceteris paribus. The OLS estimate of this relationship is lower (.205), but the significance of the effect is greater ($p < .01$) than the significance level of the TSLS estimate ($p < .05$). Again, the reason for this difference may be due to the simultaneous equation bias which makes all statistical tests using OLS estimates questionable.

With the other variables in the model, only minor differences are found in coefficient size and significance. This result may not always be the case and in other studies there can be sizeable differences in OLS and TSLS estimates among both exogeneous and endogenous regressors. The striking difference in OLS

and TSLS results for PTATT, and somewhat for PTECON, is reason enough to justify the use of TSLS: we are certain of obtaining consistent parameter estimates, and it is often the effect of these endogenous variables which are of most interest in a study.

A more detailed discussion and interpretation of the equation results is not germane. Attention will now be focused on the meaning of the OLS estimates of the reduced-form equations.

Reduced Form Results

The reduced-form equations provide different information about the effects of exogenous variables in the model on economic achievement. The OLS estimates of the reduced-form equation 3 indicate, as did the OLS and TSLS estimates of the structural equation 1, that the total effect of SES, PRECON, and GROUP treatment are all positive and significantly important in prediction of PTECON, ceteris paribus. What needs to be remembered, however, is that the reduced-form estimates represent the combination of both direct and indirect effects of a variable whereas the structural equation estimates are simply estimates of the direct effects of the variables.

To illustrate, the reduced form coefficient for the GROUP variable in equation 4 represents the direct effect (γ_{210}) of treatment on PTATT, plus the indirect effect ($\beta_{21}\gamma_{110}$) on PTATT due to the direct changes in PTECON from the GROUP treatment variable in equation 1. In addition, this combined direct and indirect effect is increased by the multiplier arising from the simultaneous effect of PTATT and PTECON on each other $\frac{1}{(1 - \beta_{21}\beta_{12})}$. This multiplier will usually be greater than one, so the OLS estimates for reduced-form equations, for the most part, will be greater than estimates for those same variables obtained by TSLS, if combined direct and indirect effects are both positive. In

this example the GROUP variable estimate of the total effect in the reduced-form equation 4 is 3.855, while the direct or marginal effect given in the TSLS estimate of equation 2 is the expected smaller value of 3.360.

While both PRATT and PRECON were excluded from the structural equations on theoretical grounds, the effects of these variables do appear in the reduced form estimates for each equation and can be interpreted in that context. For example, the estimates of the reduced-form equation 4 show the total effect of PRECON significantly contributes to the prediction of the PTATT and this result indicates another link between achievement and attitude in economics. In this case the link in an indirect one based on the simultaneous equation model: The coefficient estimate for PRECON understanding (X_4) in the reduced form equation 4 represents this indirect influence on PTATT ($\beta_{21}\gamma_{14}$) divided by the multiplier ($1 - \beta_{21}\beta_{12}$) from the reciprocal connection between the two endogenous variables in the model. An analysis of PRATT in equation 3 shows no total effect of this variable on PTECON.

Results from estimating the reduced-form equation 4 and the structural equation 2 show both a significant effect of either PRECON or PTECON on PTATT. In contrast, results from estimating the reduced form equation 3 and the structural equation 1 reveal no substantial influence of either PRATT or PTATT on PTECON. Much speculation about the importance of attitude on achievement is called into question by these results. These findings suggest that achievement in economics probably has a much stronger effect on attitude towards the subject than attitudes have on achievement. One direct method, therefore, for improving attitudes towards economics would be the improvement of the economic understanding in the classroom.

Other Evidence

Although the simultaneity problem has been explored and the difference between OLS and TSLS results has been documented, the skeptic may want more evidence than is provided by one example at the elementary level. This skepticism is reasonable and is important to the advancement of research. In fact, in a recent review of the economic education literature Becker (1983b) stated that "if economic education research is to be valuable to other practitioners, questions related to the reliability and generalizability of results must be raised" (p. 13). Consequently, three other studies with similar two-equation models will be briefly described and the OLS and TSLS results for the endogeneous variables compared to provide a stronger base for our initial finding about achievement and attitude.

Trade-offs Study: Another elementary level study of the impact of "Trade-offs" on student understanding and attitudes (Walstad, 1980). The model is very similar to our previous USMES study and the sample consisted of 563 fifth and sixth grade students. In this linear two-equation model, PTECON was considered to be a function of: PTATT; AGE; SEX; PRECON; RMC (reading and math ability); and GROUP treatment. On the other hand, PTATT was considered to be a function of: PTECON; AGE; SEX; PRATT; RMC; and GROUP.

Principles Study: Data on a 137 student sample from principles of economics classes at Millikan University were collected during a semester and analyzed using OLS in a study by Manahan and Hodgins (1978). These data were obtained from the authors and the following two-equation structural model specified: PTECON was considered to be dependent on: PTATT; AGE; SEX; PRECON, ACT (ACT score), CLASS (class standing); INST (instructor); and TIME (class time). PTATT was specified as being explained by: PTECON; AGE; SEX; PRATT; ACT; CLASS; INST; and, TIME.

Teacher Study: The USMES study of elementary student economic understanding and attitudes in a school district also was the source of a data set on a sample of 44 teachers. The two-equation model for teachers specified PTECON to be a function of: PTATT; AGE; SEX; PRECON; GCRED (number of graduate credits); and, GROUP treatment. In contrast, PTATT was considered to be a function of: PTECON; AGE; SEX; PRATT; GCRED; and, GROUP.

The problems with a single-equation approach to achievement-attitude research can be demonstrated by comparing OLS and TSLS coefficient estimates in each of the studies. Results from the previously discussed USMES study will also be included for comparison purposes. For the sake of parsimony, only the OLS and TSLS estimates for the endogenous regressor in each of the two-equation models is presented in Table 2.

Insert Table 2 about here

In three of the four studies the OLS estimates in equation 1 indicate that PTATT significantly influences PTECON, and in all four cases, OLS results suggest that PTECON directly contributes to PTATT. These results were expected since previous single-equation research has indicated that achievement and attitude tend to be "mutually reinforcing." On the other hand, the TSLS results contradict a major conclusion based on the OLS estimates. In no study does PTATT directly and significantly contribute to PTECON and OLS appears to overestimate the size of the attitude coefficient. The impact, then, of post-attitude on post-achievement appears to be negligible.

As originally expected from prior OLS research and confirmed by the TSLS estimates in PTATT equation, PTECON does appear to significantly contribute to PTATT in all studies. OLS apparently underestimated the PTECON coefficient size and in several cases overstated the significance. The TSLS results also show

that the influence of PTECON on PTATT appears to be greater in the USMES study ($p < .05$) than in the other studies ($p < .10$). PTECON appears to have a direct impact on PTATT, but we cannot always be as confident as we might wish to be in our rejection of the null hypothesis.

These results, of course, do not provide conclusive proof of the direction of the achievement-attitude relationship. An attempt was made to examine the problem in a general manner using multiple data sets and age levels, but each two-equation model is slightly different and variables are measured with different instruments. The basic model may also be misspecified and data from other age levels needs to be examined. Despite these differences, the clarity of the TSLS results across various studies challenges the previously held view and may suggest an answer to the Paden and Moyer concern (p. 3) over the direction of causation between achievement and attitude. Economics achievement may significantly influence attitudes towards economics, but attitudes towards economics appears to have little impact on economics achievement. In policy terms, time spent by an instructor helping students improve their achievement in the subject may have a direct payoff in helping to improve attitudes towards the subject, while focusing on attitudinal improvement appears to have no direct payoff for the student achievement.

Alternative Models and Estimation Procedures

The classroom world is complex. Although we have moved from simple single-equation models to more sophisticated nonrecursive models to express the process producing economics achievement and attitude, questions can still be raised concerning the validity of this new characterization. Chizmar and Zak (1983a, b), for example, find fault with the simultaneous equations approach for several reasons and suggest alternative stimation procedures. From their perspective, a

simultaneous system would be the appropriate way to handle the production of multiple products (i.e., achievement and attitude), where each output is produced under separate production processes. Their representation of a simultaneous model is stated in 5 and 6:

(5) $Y_1 = F(Y_2, X_1, X_2, \ldots, X_n)$

(6) $Y_2 = G(Y_2, X_1, X_2, \ldots, X_n)$

where Y_1 represents achievement; Y_2 represents attitude; and the X_i's ($i = 1, 2, \ldots n$) are inputs. This model, with a few exceptions, is a restatement of the earlier conceptual model in X's and Y's (see p. 4).[6]

Chizmar and Zak contend that outputs are produced jointly in the classroom and inputs are shared in the production of the joint output. To reflect this position, a single-equation model is specified which is restricted for estimation purposes to satisfy the functional form:

(7) $f(Y_1, Y_2) = g(X_1, X_2, \ldots X_n)$

Canonical correlation procedures are used to estimate this joint production function.[7]

Besides the possible problem of jointness in production, the second criticism of the simultaneous approach supposedly involves the time sequence at which the "final" and "intermediate" outputs are measured. The second problem can be used to highlight the basic differences in assumptions between the two different models.

> The problem is, perhaps, best illustrated with an example. A farm produces two ouputs in year t: cattle and corn. Land, labor, and other factors go into the production of both corn and cattle; in addition, corn is used as an input in the production of cattle. The relevant quantity of corn (for use as an input is not year t's crop, but rather the amount produced n the previous time period (t-1)).

> Thus, educational production functions that estimate both cognitive and affective achievement at time t should use affective achievement in period t-1 as an input into the production of cognitive achievement at time t. However, once this is done the link that makes simultaneous equation techniques applicable is broken. (1983b, p. 3)

It is the analogy which breaks down, however, not the simultaneous equations approach. What is true for the farm may not be true for the classroom. Time t corn obviously does not influence time t cattle, or vice versa, but may not time t achievement influence time t attitude, or vice versa? A reciprocal relationship between achievement and attitude at time t is certainly possible and is one which has been discussed on many occasions in the research literature. If a simultaneous relationship between Y_1 and Y_2 is strongly suspected, based on theory or prior research, then a simultaneous equation model should be specified, as in equations 5 or 6, and TSLS can be used to obtain consistent parameter estimates.

On the other hand, Chizmar and Zak assume that the simultaneous relationship does not exist, and that is why the "link that makes simultaneous equations techniques applicable is broken." (Note in function 8 that no endogenous variables appear on the right-hand side of that expression). Instead they specify a single-equation model which captures the perceived joint output and shared inputs relationships. The canonical correlation estimation procedures appear to be appropriate given their assumptions and concerns about estimating this joint production function. Whether this model is more plausible or "conceptually superior" is a question that cannot be answered from the analysis. The model is not directly comparable with a simultaneous one since it addresses different questions, make different assumptions, and is a different specification.

In general, with any research problem such as the relationship between achievement and attitude, there are likely to be alternative approaches which should be considered. For each study, a judgment has to be made by researchers and consumers of research about the validity of the specified model (simultaneous or otherwise). Maybe an alternative model provides a better characterization of reality or helps us answer other important questions. Determining the validity of a model is not simply an empirical issue, and is not as clear-cut as the selection of reliable statistical procedures. Ideally what we search for is a valid model and reliable methods to estimate a model of the complex world in the classroom.

Conclusion

The problem of simultaneity in learning models has only recently been recognized in economic education research. When endogeneous variables are simultaneously related in a system of equations, this feature requires the use of alternative statistical estimation procedures, such as two-stage least squares (TSLS) versus the traditional use of ordinary least squares (OLS). This chapter provided a detailed explanation of the statistical problems with using OLS rather than TSLS in the context of simultaneous structural equations. A demonstration of the OLS and TSLS estimation procedures was offered, using as an example the possible simultaneous relationship between economics achievement and attitudes towards economics which has been extensively discussed in the economic education literature. Alternative models to a simultaneous specification were also reviewed that suggested the achievement-attitude relationship was one requiring joint product rather than simultaneous modeling and estimation procedures.

FOOTNOTES

[1]For other examples of simultaneous structural equation models see Becker and Salemi (1977), Swan (1979), or Allison (1982). For discussion in the education literature consult Anderson (1978). Siegfried and Fels (1979) describe other types of affective outcomes which have been measured in economic education research.

[2]For the purpose of this paper, pre-test achievement and pre-test attitude are considered to be exogenous variables. Using a more technical distinction, these variables are lagged endogenous variables. If it customary to call exogenous and lagged endogenous variables together predetermined variables. There are problems with this distinction, as has been noted by Maddala (1977, p. 238) among others.

[3]In more formal terms, an estimator is consistent if for any $\delta > 0$,

$\lim_{N\to\infty} \text{Prob}\,(|\hat{\beta} - \beta| < \delta) = 1$, or $\text{plim}\ \hat{\beta} = \beta$.

[4]Indirect least squares, which uses OLS estimates, can also be used to derive the unique parameter estimates which are identical with the TSLS estimates when the equations of the model are exactly identified. See the identification section for an explanation of "exactly identified."

[5]For another example drawn from the economics literature to demonstrate this point, see Maddala (pp. 237-242).

[6]This model may differ from the earlier model since in the earlier model [B] does not necessarily have to equal [C]. The two model expression can be made to the same by restricting some of the X_i's to be zero, if necessary.

[7]The use of canonical correlation with examples is provided in those studies and will not be described here. A basic explanation of canonical correlation is also provided in Pedhazer (1982) and a large scale study which uses both TSLS and canonical correlation is found with Cohn and Millman (1975). The first example in the economic education literature is found in Marlin and Niss (1980).

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TABLE 1

Achievement-Attitude Results for USMES Study

(t-statistics are shown in parentheses: N = 333)

	Structural Eq. 1		Structural Eq. 2		Reduced-Form Eqs. 3 and 4	
Regressors	OLS	TSLS	OLS	TSLS	OLS (Eq. 3)	OLS (Eq.4)
Y_1 PTECON	n.a.	n.a.	.205 (3.275)**	.223 (2.316)*	n.a.	n.a.
Y_2 PIATT	.086 (2.445)*	.087 (.745)	n.a.	n.a.	n.a.	n.a.
X_1 AGE	-.027 (-.821)	-.027 (-.821)	.025 (.496)	.025 (.518)	-.025 (-.762)	.019 (.398)
X_2 SEX	-.121 (-.344)	-.121 (-.341)	.358 (.684)	.357 (.680)	-.091 (-.259)	.335 (.635)
X_3 SES	.005 (2.391)*	.005 (2.379)*	.002 (.496)	.002 (.421)	.006 (2.475)*	.003 (.804)
X_4 PRECON	.755 (15.177)**	.755 (13.288)**	n.a.	n.a.	.769 (15.34)**	.172 (2.297)**
X_5 PRATT	n.a.	n.a.	.310 (5.684)**	.309 (5.562)**	.027 (.739)	.214 (5.680)**
X_6 GRADE 4	-1.589 (-1.779)	-1.579 (-1.757)	-.535 (.402)	-.494 (-.368)	-1.654 (-1.847)	-.864 (-.646)
X_7 GRADE 5	-.799 (-1.179)	-.799 (-1.172)	.129 (.127)	.138 (.135)	-.803 (-1.168)	-.042 (-.408)
X_8 ABSENCES	.071 (.867)	.071 (.865)	-.082 (-.672)	-.081 (-.664)	.065 (.790)	-.067 (-.539)
X_9 TECON	.013 (.385)	.013 (.375)	.062 (1.280)	.062 (1.280)	.018 (.557)	.066 (1.350)
X_{10} GROUP	1.885 (3.879)**	1.882 (2.942)**	3.406 (4.757)**	3.360 (4.542)**	2.218 (4.700)**	3.855 (5.472)**
X_0 CONSTANT	2.864 (.603)	2.847 (.548)	9.029 (1.256)	8.997 (1.251)	3.704 (.762)	9.824 (1.355)
Adj.R^2	.517	.517	.232	.232	.509	.220
SEE	3.174	3.174	4.738	4.739	3.201	4.777
Total eq. F	36.602**	36.602**	11.047**	11.036**	35.462**	10.338**

*Significant at the .05 level
**Significant at the .01 level

Table 2

Achievement-Attitude Model Coefficient

Estimates for Endogenous Regressors Only

(t-statistics in parenthises)

Samples and Regressors	Dependent Variables and Equations			
	PTECON: EQ 1		PTATT: EQ 2	
	OLS	TSLS	OLS	TSLS
1. "USMES" (elementary)				
Y_1 PTECON	n.a.	n.a.	.205 (3.275)**	.223 (2.316)*
Y_2 PTATT	.086 (2.445)*	.087 (.745)	n.a.	n.a.
2. "Trade-offs" (elementary)				
Y_1PTECON	n.a.	n.a.	.200 (3.44)**	.272 (1.81)#
Y_2PTATT	.062 (2.37)*	-.051 (-.79)	n.a.	n.a.
3. "Principles" (college)				
Y_1 PTECON	n.a.	n.a.	.479 (3.583)**	.704 (1.84)#
Y_2 PTATT	.129 (3.00)**	.043 (.43)	n.a.	n.a.
4. "Teacher" (adult)				
Y_1 PTECON	n.a.	n.a.	.209 (1.82)#	.287 (1.76)#
Y_2 PTATT	.101 (.64)	-.189 (-.37)	n.a.	n.a.

#Significant at the .10 level (two-tailed test)

*Significant at the .05 level (two-tailed test)

**Significant at the .01 level (two-tailed test)